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A monthly survey by the U. S. National Committee for the International Geophysical Year. Established by and part of the National Academy of Sciences, the Committee is responsible for the U. S. International Geophysical Year program in which several hundred American scientists are participating and many public and private institutions are cooperating.

First Sea Surface Gravimeter

The first successful surface measurements of gravity in the open sea were made on November 22, 1957, by J. Lamar Worzel, Assistant Director of the Lamont Geological Observatory at Columbia University, using a new sea gravimeter developed by Anton Graf of Munich. The instrument was mounted on a gyro-stabilized platform installed aboard the USS *Compass Island.* (The *Compass Island,* one of the few vessels on which a stabilized platform is installed, was made available for this work by Captain L. L. Schork of the U. S. Navy's Bureau of Ordnance.)

Gravity values for ocean areas have, in the past, had to be measured in submarines submerged to quiet depths. Difficulties in obtaining and fitting submarines for this purpose greatly restricted the accumulation of gravity data for the 80 percent of the earth's surface that is covered by water. The new sea gravimeter now makes it possible to take gravity measurements simply and expeditiously in moderately calm seas any place on the ocean surfaces of the earth, thus assuring that data long needed but difficult or impossible to obtain will now be available.

To date there have been only about 5000 measurements of gravity made at sea throughout the world. A device for multiplying the volume of such data is therefore of the greatest importance for the objectives of the IGY gravity program. This program seeks (1) to fill in the major gaps in a world gravity network, principally in the Arctic, Antarctic, and ocean areas, and (2) to relate existing networks, generally national in character, to each other so as to produce a first-order international network. Attainment of these objectives will greatly improve gravimetric mapping, which offers the fastest and most accurate method for linking all maps to a common reference system, and add much to knowledge of the earth's shape and the distribution of its mass.

Roughly half of the existing sea surface gravity measurements have been made by the Lamont Geological Observatory in the past 10 years, using pendulums carried in submerged submarines. Gravity measurements at sea were begun as recently as 1927 by Vening Meinesz, who developed a pendulum apparatus for use on the spongy soil of Holland. Meinesz found that his pendulums could be used in submarines to take gravity readings in the open sea, and it was he who made most of the 1,200 oceanic gravity measurements recorded by the end of World War II. Since the end of the war, British and Dutch scientists, in addition to those at Lamont, have conducted submarine gravity programs.

The new sea surface gravimeter has additional advantages over the standard submarine pendulums. Surface gravity measurements from the USS *Compass Island* were

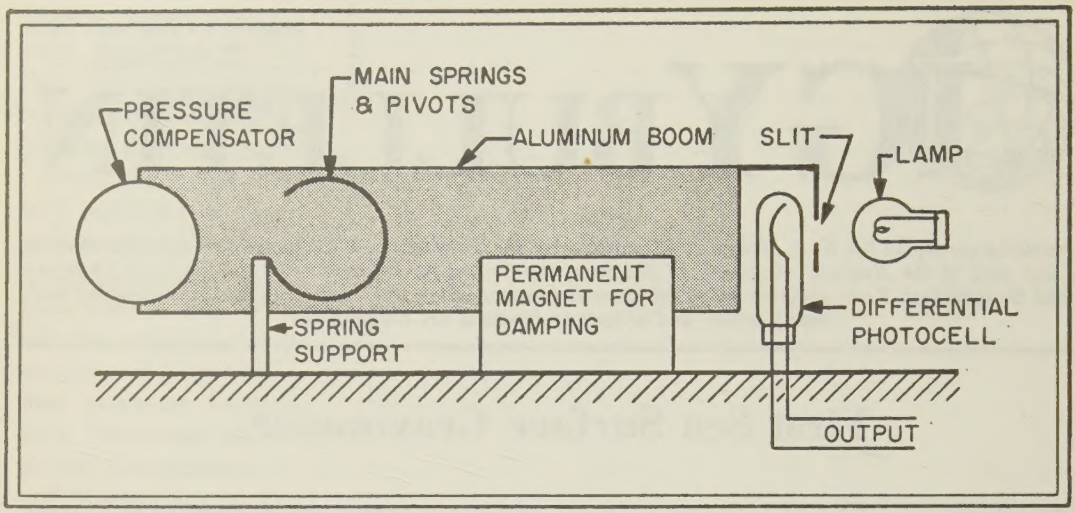

Fig. 1.

taken in nine hours, as compared with two days for earlier submarine measurements of comparable areas. The data were reduced in just one-half day, as compared with two weeks needed to adjust and compute data from submarine measurements.

The USS *Compass Island* left New York November 18 and returned November 22. To evaluate the accuracy of the Graf sea gravimeter, which had previously been tested on a surface ship only on a lake and the Adriatic Sea, the surface measurements were begun 200 miles southeast of New York on November 22, at a point where measurements had been taken aboard the submarine USS *Tusk* in 1947. The surface measurements were continued on a track which closely duplicated the *Tusk's*, moving from the deep ocean basin across the continental slope and onto the continental shelf, ending off Fire Island, New York.

The Graf sea gravimeter consists of a

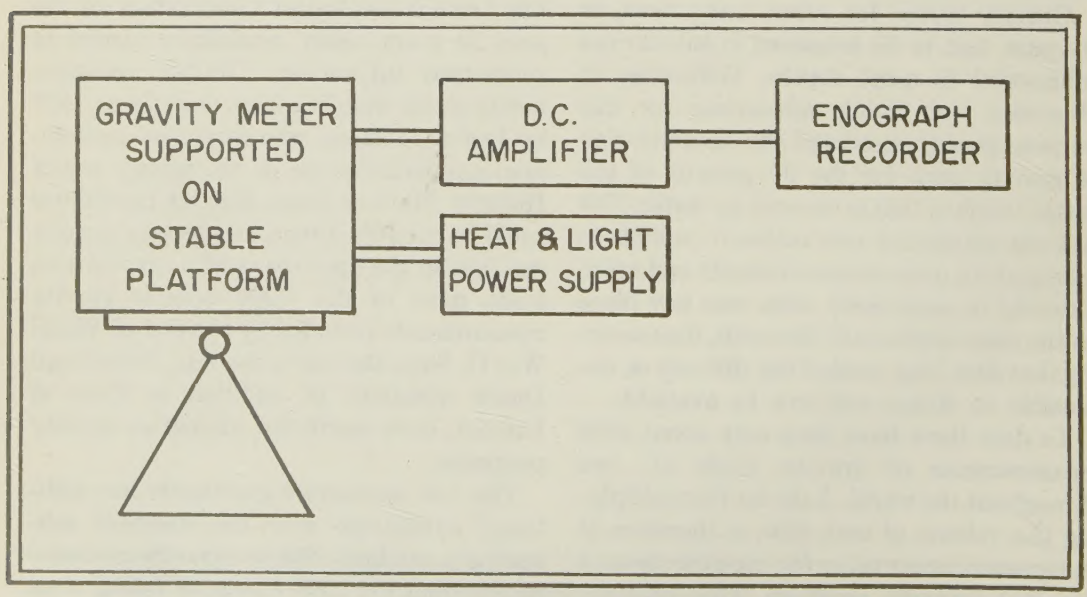

Fig. 2.

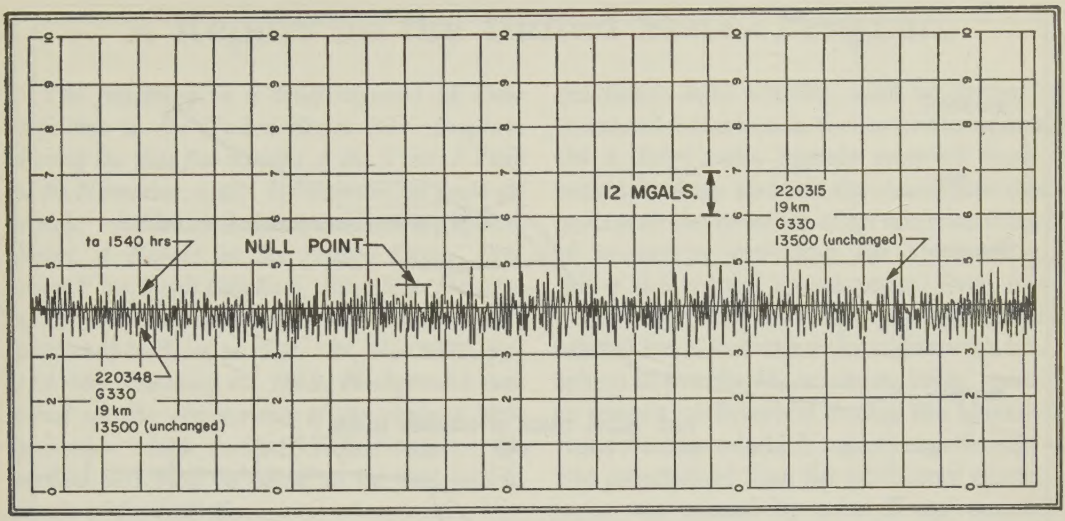

Fig. 3.

horizontal aluminum boom sprung and pivoted on horizontal cylindrical springs near one end (see Fig. 1). The position of the boom is determined by a differential photocell which is activated by a lamp illuminating a slit attached to the boom. The field of a large permanent magnet is cut by the aluminum boom, providing eddy current damping when the boom moves. The small instrumental volume results in air pressure compensation. The system is largely temperature-compensated; it is enclosed in a doubly-thermostated oven maintaining the temperature within about 0.01°C.

Figure 2 is a block diagram of the system. The output of the gravimeter is amplified in the d.c. amplifier, further damped electrically, and then recorded on an Enograph recorder, a self-balancing potentiometer-type recorder.

The operation of the equipment consists of establishing the meter on the stable platform and levelling it. The springs are adjusted to bring the boom close to the instrument null point, as indicated by the Enograph recorder. The wave accelerations appear as fluctuations of the recorder trace about a mean position. The damping of the overall system is such that wave accelerations with periods of six seconds are reduced by a factor of 10,000, and wave accelerations with periods of ten seconds are reduced by a factor of 3000. The time constant of the highly-damped system is such that a change of gravity requires five minutes for its complete registration.

The dial reading at the null point is computed from the dial setting combined with the mean position of the boom indicated by the recorder. The scale constant of the meter and observations at base points permit one to calculate the gravity reading for each five- to ten-minute section of the record.

Certain types of corrections are made for each observation. The ship has a centrifugal acceleration owing to the rotation of the earth; it is necessary to make a correction (the Eötvös correction) of this acceleration because of the east-west component of the ship's speed. Later, the effects of current can be estimated from the ship's navigation plot. The resultant observed gravity is then available for such anomaly computations as desired.

Figure 3 shows approximately a one-half hour section of the record made on board USS *Compass Island* The wave periods were about eight seconds and maximum vertical accelerations of 140,000 milligals peak to peak are indicated as about 20 milligals peak to peak on the record.

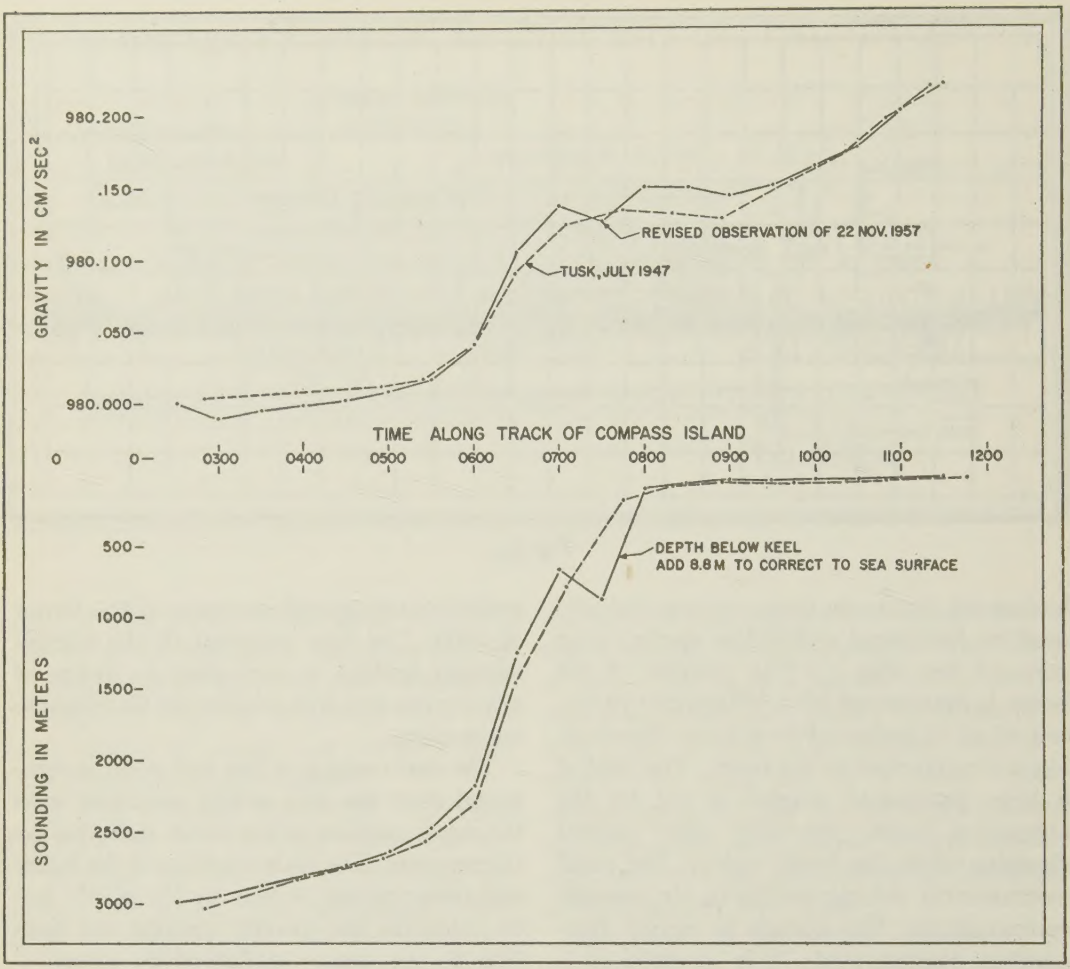

Fig. 4.

Figure 4 shows a plot of the observed gravity values at half-hour intervals on USS *Compass Island* and the observations of USS *Tusk* projected to the track of USS *Compass Island*. The bottom half of Figure 5 shows the corrected soundings obtained on each ship at the same time that the gravity readings were made. The comparison of these data is considered extremely satisfactory in view of the differences in the observation positions and the much poorer navigation data accompanying the USS *Tusk* observations with respect to both position determination and the Eötvös corrections.

Lamont scientists plan to continue to test the Graf sea gravimeter throughout the IGY, and they hope that it will eventually take its place aboard all oceanographic research vessels and become a standard method of gravity measurement.

A Report on the United States Program

The following is a brief account of some activities in the United States IGY program during the first five months of the Year, 1 July to 30 November, 1957. It is condensed from an article entitled "International Geophysical Year: A Report on the United States Program," by Hugh Odishaw, Executive Director of the US National Committee for the IGY, published in Science, *Vol. 127, No. 3290, pp. 115–128, January 17, 1958. Background material on the dimensions of the various programs in which early IGY findings are described here may be found in the first several issues of the Bulletin.*

Physics of the Upper Atmosphere

Solar Activity: On the eve of the IGY's beginning, the first major solar flare of the program, that of 28 June 1957, was observed at the Krasnaya Pakhra Observatory in the Soviet Union. A message was flashed to the World Warning Agency operated for the IGY by the National Bureau of Standards at Fort Belvoir, Virginia, which declared a state of Alert beginning at 1600 UT, 28 June. (Alerts are declared when there is probability of solar disturbances. When the probability is high that terrestrial disturbances will also occur, Special World Intervals are promulgated calling for increased measurements of solar-terrestrial phenomena.) The first such interval in IGY was broadcast on June 29, to commence at 0001 UT 30 June. Throughout the world observations of the sun were intensified, and balloons and instrumented rockets were sent up by many nations to observe the increased ultraviolet and X-radiation and to monitor cosmic ray intensity. Observations and measurements were speeded up to record more carefully and fully the northern and southern lights, to measure disturbances in the earth's magnetic field, and to probe the ionosphere.

It had long been thought, but not heretofore conclusively established, that absorption of radio signals during such periods of maximum solar activity must be caused by increased ionization in the lower atmosphere. On 4 July, radio signals received from a rocket fired up through the ionosphere demonstrated the presence of an additional layer of ionization extending for about 12 mi below the normal lowest point. Even more remarkably, the rocket data showed that the normal ion distribution throughout the ionosphere above the D, or lowest, layer, seemed to remain undisturbed during the blackout. In another recent IGY rocket experiment, it was ascertained that the additional electron layer was caused by solar X-ray emission associated with the occurrence of solar flares.

In another portion of the IGY program, at the Mount Wilson Observatory in California, measurements are being made of the magnetic field of the sun at its surface. It has already been found that magnetic fields at the sun's surface may be very high, as much as 8,000 times that of the earth's field at the equator. These magnetic fields are thought to play a very important role in disturbances and storms on the sun's surface as well as in sunspots.

It has been suggested, but not previously established, that the magnetic effects we observe on earth during magnetic storms may be due to great electric currents, of perhaps several hundred thousand amperes, flowing around the earth high in the atmosphere. Two of these currents are believed to circle the North and South magnetic poles while the third circles the earth at the geomagnetic equator.

Stations in South America and in the Pacific Ocean—at Guam and Koror in the Western Pacific, and at Jarvis, Palmyra, and Fanning Islands in the Eastern Pacific—were established especially to study the existence of the so-called "electro-jet." The electro-jet is believed to be the equatorial electric current, but narrowed down into a "neck" of limited horizontal dimensions with consequent increased current density and intensified activity at local noon. The US

Coast and Geodetic Survey, which operates many of the magnetic observatories established by the United States, reports tentative confirmation of this phenomenon. Initial data from Koror reveal the existence of the equatorial electro-jet and its rather limited horizontal extent.

Aurora and Airglow: The 39 stations and hundreds of amateurs participating in the United States program have already had much to observe. The fact that the IGY was scheduled for a period of expected maximum solar activity has greatly enhanced the value of the program, for already three of the largest solar flares (class 3+) have resulted in extensive auroral displays visible as far south as Havana, Cuba. Synoptic maps have been prepared depicting all auroras observed and reported from the United States during the months of July and August. This is the first time that such a complete description of auroral data has been assembled for the use of geophysicists studying auroral and such related phenomena as ionospheric and geomagnetic effects.

English scientists at the University of Manchester have reported that coordinated radar observations indicate that auroras occur simultaneously in the Northern and Southern Hemispheres, a condition long believed to be true by scientists, but not previously established. Additional polar radio data which provide further evidence on this question have been obtained in the United States program.

The systematic reduction of the variations in the intensity of the night airglow is proceeding. Charts of the "patchiness" and movement of night sky luminosity resulting from oxygen emissions are being produced on a routine basis from IGY observations.

Ionospheric Physics: New information about the farthest reaches of the atmosphere is being obtained from the study of "whistlers"—whistle-like sounds which can be detected at very low radio frequencies. These signals, originating in lightning flashes at the surface of the earth, swing out thousands of miles along the earth's lines of magnetic force before they return to earth in the opposite polar hemisphere. Early IGY experiments demonstrated that the ion density and molecular concentration along the whistler path at altitudes of as much as twice the earth's radius must be much greater than formerly anticipated. Indeed, there seems to be confirmation for the theory that the earth's atmosphere extends far beyond the level where it had been previously thought to "end" and that there may be a very tenuous atmosphere—the sun's corona—filling all the space between the earth and the sun.

Other records of previously unexplained radio noise at very low frequencies have stimulated the hypothesis that solar particles arriving in the very high atmosphere transfer energy to very low frequency radio waves there. According to this hypothesis, the radio signals thus amplified are the very low frequency radio emissions observed at ground level. Data now being gathered will throw further light on this hypothesis, which is based on the traveling wave tube principle as noted by Roger Gallet.

Ionospheric characteristics are deduced from the analysis of echoes arising from the reflection of radio pulses transmitted to the ionosphere at vertical incidence. Since the IGY began there have been several major solar events that caused disruption of long-range, short-wave radio communications which depend upon reflections from the ionosphere. For the first time, a synoptic picture has been obtained of the growth and decay, station by station, of such fadeouts.

The principal, regular variation in the ionosphere is the diurnal one. Ionization density increases during the day, when the sun is present, and decreases at night. What would happen to the ionosphere during long absences of solar radiation and the nature of any diurnal variation during such periods have been subjects of speculation. Only at or near the geographical poles can these questions be examined, and the South Pole affords the best platform for an observatory. Investigations during the last year at the

South Pole Station of the United States have yielded interesting results: in spite of the absence of the sun, the electron concentration seems to remain very high throughout the polar night; moreover, there is a diurnal variation that can only, it appears, be associated with geomagnetic activity. The evidence so far obtained suggests that ionospheric behavior in the two polar regions is essentially the same. Analysis of these observations may appreciably alter our concepts of the ionization and recombination processes in the atmosphere.

Cosmic Rays: These electrically-charged particles, which bombard the earth continuously and from every direction, are markedly influenced by the earth's magnetic field: low energy particles are deflected toward the vicinity of the two geomagnetic poles, and only the more energetic ones penetrate at the middle latitudes.

Investigations at the 20 United States cosmic ray stations have already provided interesting results. The work of scientists from the University of Chicago has shown that the location of the line where the cosmic ray intensity is a minimum—the "cosmic ray equator"—deviates systematically from the geomagnetic equator. The experiments leading to this result began in 1954–55 when a neutron pile detector was installed aboard the USS *Atka*, which conducted a reconnaissance of the Antarctic prior to the establishment of IGY stations in following years. Measurements were made on the trip down, around Antarctica, and back; these measurements were repeated in the 1955–56 and 1956–57 Antarctic seasons aboard the USS *Arneb* and were supplemented by aircraft flights in a zigzag pattern around the geographical equator in October 1956. These studies showed a 40° to 45° shift to the west of the inclined cosmic ray equator with respect to the magnetic equator. J. A. Simpson suggests that this warping may well indicate the presence of important magnetic fields, probably of extraterrestrial origin, which alter the trajectories of the incoming primary cosmic ray particles.

Typical of international cooperation in this program during the IGY is the Swedish-Canadian-American cosmic ray experiment carried out aboard the Swedish merchant ship M/S *Lommaren* sailing between Sweden and the Union of South Africa.

Preliminary balloon flights in and near Minnesota with ionization chambers have shown that, at constant altitude, there is a strong latitude effect. This is so strong that latitude changes as small as 7 mi can be detected by cosmic ray measurements. Other balloon experiments at Fort Churchill and Thule have shown that cosmic rays of lower energy (less than about 2 Bev) effectively disappeared during the present period of high solar activity, with ionization at high altitudes down to half the value it had in 1954 or 1955.

Perhaps one of the most interesting observations made in the course of IGY cosmic ray experiments was that of relatively soft radiation in the high atmosphere, associated with primary auroral radiations. Rocket and balloon flights have led to the positive identification of the soft radiation: it is X-radiation in the range between 10^4 and 10^5 electron volts. There appears to be good correlation between the presence of such radiation and solar, magnetic, and auroral activity. The effect is probably a secondary one; it is believed that incoming auroral particles create the X-rays by bombardment of atmospheric particles.

There were 29 rockets fired in the pre-IGY test period. These included Aerobees, Rockoons and Nike-Cajuns. Firings took place at the newly erected facilities at Fort Churchill (with Canadian cooperation) as well as at White Sands, New Mexico, Guam, and from shipboard off the California coast and in the North Atlantic. These firings were successful, and the preliminary information gained was of considerable value in the final detailed planning of the schedules for firings during the IGY period.

The United States IGY program in rocketry actually began on 5 July 1956 at Wallop's Island, Virginia, when the first IGY

test rocket was fired successfully. To date, 83 rockets have been fired during the IGY. Included have been those in programs conducted at Fort Churchill (nine Aerobees, five Nike-Cajuns); White Sands (two Nike-Cajuns); Point Mugu, San Nicolas Island, California (13 Nike-Deacons); a shipborne operation in the Arctic (18 Rockoons) and a shipborne operation in Pacific and Antarctic waters, concluded in mid-November (36 Rockoons). The following are some preliminary findings:

1. A firing at Fort Churchill indicated that the first atmospheric temperature maximum occurred at an altitude of about 60 km. Normally, this maximum is found below 50 km at lower latitudes, indicating that, at northern latitudes, the rise is more gradual. (Temperatures decrease up to the stratosphere, rise during the next 20 to 30 km, decrease through the next 30 km, and then rise again.)

2. A rocket instrumented for ionospheric studies was sent through a polar radio blackout for the first time. Data were obtained which indicated that a very dense D-region exists at a significantly lower altitude and with a much greater density than is found at lower latitudes.

Another firing at Fort Churchill during the summer of 1957 measured electron distribution in the ionosphere up to an altitude of 250 km during a polar blackout. The results of this experiment confirmed theories that the D-region of the ionosphere is primarily responsible for radio blackouts.

3. During a series of firings with Aerobees and Nike-Cajuns instrumented for studies of pressure, temperature, and density, it was determined that the distribution of pressure and temperature in the atmosphere at high latitudes is much different than it is at lower latitudes. Many of these rockets attained altitudes greater than 200 km, and thus the first density measurements made at high latitudes were recorded. Launchings were made during both summer and winter, day and night. The resulting data indicate that the density of the high atmosphere is under strong solar control. There appear to be a latitude effect, a seasonal effect, and a strong diurnal effect; none of these effects appears at lower altitudes at Fort Churchill or lower latitudes.

4. An experiment with a mass spectrometer at Fort Churchill appears to confirm the belief that diffusive separation of gases under gravity is present above 100 km at that latitude. Below this point the gases in the atmosphere appear to be well mixed.

5. During July and August 1957 the DAN rocket flare patrol program took place at Point Mugu, California. This program was primarily directed toward determining the radiation source of the fadeouts resulting from flares observed on the disc of the sun. For the first time, measurements were made of X-ray and ultraviolet bursts from the sun during a solar flare. These data will help in explaining radio blackouts, which are present during periods of unusually high degree of ionization and which are closely associated with solar flares.

6. During the shipboard firings in the Arctic, an excellent survey was made for the first time of auroral particles and their association with actual auroras. Also conducted for the first time at high latitudes were magnetic field measurements.

Satellites represent an extension of rocketry useful in probing the high atmosphere. The USSR launched its first satellite on 4 October 1957. This satellite, a sphere nearly 23 inches in diameter and weighing about 184 pounds, carried transmitters broadcasting on frequencies of 20 and 40 mc/sec. The second Soviet satellite was launched on 3 November. Weighing about 1120 pounds, the last rocket stage was reported to carry two transmitters (20 and 40 mc), a dog, and instruments to measure satellite temperatures, ultraviolet light, X-rays, and cosmic rays. The initial period of the second satellite's revolution was 103.7 min with an apogee of approximately 1056 mi and perigee of about 150 mi.

The United States program is proceeding

according to schedule. The Navy has responsibility for the rocket system and launching in the Vanguard series, the Army for the Jupiter-C series. The IGY Committee of the Academy is responsible for the scientific aspects, both internal experiments and the radio and optical observation programs. Two types of satellites have been designed: test spheres for use during the test period for the Vanguard rocket system and equipment-laden satellites thereafter for both the Vanguard and Jupiter-C vehicles.

Earth's Heat and Water Regimen

Meteorology: For the first time, synoptic meteorological charts of the vast unknown continent of Antarctica are being drawn on a daily basis at the Antarctic Weather Central, operated at Little America with the aid of scientists from a number of nations. As a result, weather forecasting has already been markedly improved in the Southern Hemisphere. Aside from the forecasting and synoptic aspect, the scientific value of the observations in Antarctica are potentially of great value in understanding atmospheric circulation and its relation to solar radiation and topography.

The Antarctic is the coldest place on earth. The continent itself is elevated and mountainous, the South Pole being almost 10,000 ft above sea level. Last September 17, the South Pole Station reported the lowest temperature yet recorded, 102.1° below zero.

In the Antarctic meteorology program, large neoprene balloons have been sent to altitudes of over 80,000 ft, and the average is about 60,000 ft. Meteorological balloons sent up at 112 non-Antarctic United States stations are reaching altitudes ranging from 85,000 to 107,000 ft.

In addition to these broad-scale programs, several specialized programs are underway, and preliminary results have been received. For example, there is in Little America an instrument which measures the minute quantity of ozone in the air at the ground level. Ozone mainly occurs in a layer-like region about 15 mi high in the earth's atmosphere. Some ozone diffuses to the ground or is formed at lower levels by ultraviolet light. It has been noticed that, at Little America, there is about 25 per cent more ozone at the ground than there is in New Mexico. Although ozone is a minor constituent of the atmosphere, it is thought to play an important role in the circulation of the high atmosphere, because of the energy it can absorb and release.

Another minor constituent of the atmosphere which may play a major role in climatic changes is carbon dioxide. Our industrial civilization burns tremendous quantities of fossil fuel each year, pouring millions of tons of carbon dioxide into the atmosphere. Most of this is absorbed by plant life and by the waters of the oceans, but there is the possibility that eventually the carbon dioxide content of the atmosphere will rise enough to affect the world's climate. It has been found already that the concentration of carbon dioxide in the Antarctic is about the same as in non-industrial areas over the rest of the world.

Glaciology: Technical advances and discoveries have already been made in the two greatest reservoirs of ice in the world, Greenland and Antarctica. In Greenland, scientists and engineers of the US Army's Snow, Ice and Permafrost Research Establishment have perfected techniques for drilling deep holes in the ice with hollow drills, much as an oil well is drilled, to obtain a "core" of ice. The first hole was drilled in Greenland in 1956 and reached a depth of over 1000 ft. The second hole was successfully drilled in 1957 in Greenland, and a similar operation is now under way in the Antarctic in Marie Byrd Land.

The recent boring in the ice of Greenland reached a depth of 1438 ft. A complete series of cores 4 inches in diameter was obtained from the first 1040 ft. Below this depth, recovery of the core is difficult because the release of strains as the ice is drilled causes the ice to shatter. Dissolved gas, which is under great pressure in the ice

at these depths, also causes trouble because it bursts through pockets in the ice, increasing the amount of shattering. However, a core was obtained from 1200 to 1220 ft, and another from 1320 to 1338 ft. These cores are being studied with great care in the laboratory, for they are an invaluable index of climate and precipitation over the past many hundreds of years. Their layers are studied in much the same fashion as tree rings. From the first hole in Greenland, the 1912 layer was identified by the ash from a volcano which erupted in Alaska. The dust from the great explosion in 1883 of the volcano Krakatoa, in the East Indies, will be a help in checking the dating of the annual layers of precipitation in the cores. Because precipitation is lower in the Antarctic than in Greenland, it is expected that this ash layer will be found at a depth of about 150 ft in Greenland and at about 60 ft in the Antarctic.

The great ice sheet of the Antarctic, over 6 million square miles in extent, cannot be studied in anything but a spotty fashion. However, teams of glaciologists, seismologists, and support personnel are traveling by tractors and special over-snow vehicles thousands of miles across the ice in a series of traverses to obtain the profile of ice thickness across the continent and to attempt to learn something of the underlying terrain, or formation of the ice-covered earth. For example, after the Byrd Station was established some 600 mi from Little America by a tractor party, a traverse team then crossed the ice shelf from Little America and continued to Byrd Station, exploring the ice as it went. During this first traverse, it was discovered that Byrd Station, at an elevation of about 5000 ft above sea level, stands upon ice almost 10,000 ft thick. Further explorations will reveal whether this is a frozen fjord or inland sea and what part of this submergence may be due to the bending inward of the earth's crust as a result of the weight of the ice.

United States scientists at two locations in the Arctic basin are now making studies of the melting of the ice pack, the freezing of new ice, and the general relations between the state of the ice and the local climate.

Drifting Station A is now located in the region of latitude 85.30°N and longitude 170°W, 310.5 miles from the Pole. It is on the ice pack itself, on a floe a few miles in area and only some 7 to 12 ft thick. Scientists there have noted that during the past summer season about 12 inches of ice on the upper surface have melted, while as much as 18 to 24 inches of new ice have frozen on the bottom of the floe. This observation will be placed in proper perspective when all the information on radiation from the sun, ocean currents, and temperatures of the air, ice, and oceans has been studied.

Recently, in a test of instrumentation developed by J. C. Swallow of the National Institute of Oceanography in England, the *Atlantis*, a research vessel of the Woods Hole Oceanographic Institution, and the British research vessel, *Discovery II*, explored the eastern edge of the Gulf Stream and for the first time were able to map the underlying flow of water. They found that, at depths of about 6500 ft, there was either very little or erratic movement; shallower depths showed set to the northeast, as expected, but at about depths of about 9000 ft, the current sets in the opposite direction—southwest—at the relatively high speed of 8 mi per day. The Swallow neutral buoyancy float was tracked electronically in this work, providing a new technique which enables IGY oceanographers the world over to map both surface and relatively deep currents.

Several United States ships have already made extensive cruises for the IGY. The work of the *Atlantis* has already been mentioned. The *Crawford*, also of the Woods Hole Oceanographic Institution, made a four months' cruise in the *Atlantic*. The *Crawford* reoccupied many stations taken years ago by the German ship *Meteor* and discovered that there have been pronounced changes in the amount of oxygen dissolved in the Atlantic in the region of 15° South latitude. The difference in oxygen content

over the past 30 years may mean that deep bottom water is not being formed as fast now as it was previously, but further data and analysis are needed for proper interpretation of the present observations.

The *Vema*, a research vessel operated by the Lamont Geological Observatory of Columbia University, has completed an extensive cruise in the Southern Atlantic Ocean, working along the coasts of South America and Africa, and crossing the Atlantic at high southern latitudes between Argentina and Capetown. The *Vema* cooperated with the *Bahia Blanca*, a survey vessel of Argentina, in making explorations of the submarine crust by seismic methods. Considerable marine biological work was also done, and Lamont has reported that living organisms—a small shellfish and a worm one-fourth of an inch long—were recovered alive from depths of 13,200 and 16,200 ft respectively. Lamont scientists believe these to be record depths for retrieval of live marine samples. (The *Vema* has since left New York on a second cruise.)

In the Pacific, the *Brown Bear* of the University of Washington worked in the Northeast Pacific Ocean last summer. The deep currents in that area were studied. The *Horizon* and *Baird*, research vessels operated by the Scripps Institution of Oceanography of the University of California, left San Diego in October for a two-ship, five-month expedition through the Central and Southeast Pacific. They will make seismic explorations of the submarine crust, study surface and deep currents, take bottom samples and occupy about 40 oceanographic stations, where water samples down to great depths will be obtained for later analysis of chemical content. The *Jakkula*, of the Agricultural and Mechanical College of Texas, will cruise in the Caribbean Sea and western Atlantic in the summer of 1958.

Another part of the IGY oceanography program is the study of the mean sea level over the period of the IGY. It has been found from study of tide data that there seems to be an exchange of water between the Northern and Southern Hemispheres as the seasons change. New tide gauges are being set up to supplement the existing network: instruments are already operating in Bermuda, Iceland, and the Azores in the Atlantic, and in the Caroline, Marshall, and, with the cooperation of French scientists, at French islands in the Southeast Pacific. A station is in operation on Pitcairn Island under the supervision of a descendant of one of the mutineers of HMS *Bounty*.

Geophysicists on Drifting Station A, in the Arctic Ocean, reported on August 12, 1957, that the ice floe on which their station is established had floated over an underwater mountain range, or ridge, rising more than 5,000 ft above the ocean floor. The ridge was discovered in the course of routine seismic depth soundings and gravimetric measurements when the station was at 82° 54′ N, 167° 28′ W—about 850 mi northwest of Barrow, Alaska, and about 550 mi from the North Pole—drifting generally toward the Pole. The soundings indicated a rapid decrease in ocean depths, from more than 10,000 ft to slightly less than 5,000 ft. Increased gravity values indicated a corresponding substantial compensation in the crustal mass. On November 23, 1957, the station recrossed the ridge and was able to confirm its original report. Scientists of the Soviet Union are doing similar work on two stations in the Arctic Basin.

In the Antarctic the ships of the various nations supporting scientific stations on the continent engage in oceanographic observations enroute to and from the area. Thus, USSR and New Zealand ships have added to our knowledge of these waters. Ships of the US Navy Task Force 43 are also exploring the coast, charting the bottom, and taking bottom and water samples for future study.

Earth's Structure and Interior

Seismology: Several new types of seismographs with wide range and high sensitivity have been located at observatories through-

out the world. The Lamont Geological Observatory has constructed ten special long period seismographs and has installed most of them at observatories ranging from Hawaii to Fiji and from Bermuda to the Antarctic. These long-period instruments are sensitive to surface waves of periods of about 400 sec, generated only by the very largest earthquakes. These wave-lengths are so long that they penetrate to the interior of the earth, and in fact, the whole earth itself may be set into vibration. Recently, workers at Lamont have discovered the existence of certain intermediate waves with periods of about 100 sec. These waves, which were previously only known in the crust in continental structures, have been identified now in the mantle, or the next layer beneath the crust. These waves permit better resolution of structural details than the longer 400-sec waves, and study of their propagation is expected to provide new information on the distribution of materials in the interior of the earth.

Seismologists from the Department of Terrestrial Magnetism of the Carnegie Institution of Washington worked on exploration of the roots of the Andes Mountains in South America last summer and fall. They have found roots of unsuspected depths and are now working on their data to obtain better understanding of the crustal structure under this great mountain chain.

Seismologists of the US Coast and Geodetic Survey have installed new seismic equipment in the Pacific at Truk and Koror and have been obtaining records of Pacific earthquakes. These new stations, together with those in the Antarctic, will add significantly to our knowledge of seismicity and the structure of the earth.

The first successful measurements of gravity on the open sea were made on November 22, 1957, by J. Lamar Worzel of the Lamont Geological Observatory, using a sea gravimeter developed by Anton Graf of Munich. In the past, gravity measurements for oceanic areas required measurements aboard submarines at quiet depths below the surface. The difficulty of obtaining and fitting submarines for this purpose made it impossible adequately to survey the seas: only about 5,000 such measurements have been made throughout the world. The new instrument, mounted on a gyro-stabilized platform, will make it possible to obtain data simply and quickly anywhere at sea with a precision of one part per million, similar to that attainable on land.

IGY data

The preceding sections suggest the nature of the IGY activities as shown by the US IGY effort in the first few months of the program. With 67 nations cooperating in the endeavor and some 10,000 scientists and technicians making observations and measurements at more than 2,000 stations, the volume of data stemming from the program will be considerable. To ensure the safety of the raw data and their accessibility, the international IGY committee has approved the establishment of three world data centers—in the US, in Europe, and in the USSR.

Each data center will acquire a complete set of all IGY data. Each center will archive and index its compilation of data, holding it accessible to research workers. Schedules for the orderly flow of data into the centers have been arranged. These schedules vary, depending upon the nature of the data in a given discipline and upon the definition of a reasonable "lot" of data to simplify the handling problems. A "lot" of data may be one month's observations in one field or several months' in another.

The procedures for handling data and forwarding them appropriately involve a series of steps of the following kind: (i) collection of a "lot" of data at a field station, (ii) transmittal of the "lot" to the home laboratory of the field station, (iii) checking of field data at the home laboratory, (iv) transmittal to one of the World Data Centers, (v) copying of the data by one World

Data Center for the other two and appropriate transmittal, and (vi) indexing and archiving at World Data Centers.

The data centers are in operation, and data are flowing into the centers. The steps outlined above lead to a peak early in 1958, a steady 18-month plateau through at least the first six months of 1959, followed by a "clean-up" period extending probably into the first quarter or so of 1960.

Acknowledgment: The preparation of this narrative would not have been possible without the cooperation of many scientists and institutions engaged in the IGY program. Although some of them are mentioned in the text, it has not been possible in this summary to refer to all. The United States IGY program has only been possible because so many individual scientists as well as public and private institutions have participated and cooperated in the endeavor. Particular acknowledgment is made to members of the Academy's IGY staff who have helped in the preparation of this report: Stanley Ruttenberg, Phillip Mange, John Hanessian, Jr., and John Truesdale.

Satellite Telemetry

This article is based upon material furnished by Whitney Matthews of the Naval Research Laboratory and George H. Ludwig of the State University of Iowa.

In order that non-recoverable satellites may be used for direct observations in space, they must be equipped with telemetering systems—systems designed to record observations made by the satellite's instruments, to encode those observations for transmittal to ground stations and then to accomplish the actual transmission. Without such systems, only ground-based satellite experiments could be conducted. With them, instruments may be used to make observations directly in space, unhampered by an intervening atmosphere.

Special Requirements

Requirements for a telemetering system to be used in an earth satellite are much the same as for any such system, but qualities normally considered desirable become essential in satellite telemetry. The cost of putting a satellite into orbit, the longer period available for telemetry, and the impossibility of maintenance all place unusual emphasis upon reliability. The high cost in vehicle power and weight required to place each additional ounce in orbit makes it necessary to keep telemetering weight factors extremely low. To keep the system operating as long as possible on self-contained batteries, power needs must be held to the minimum.

A new and major problem in the design of satellite telemetry systems is that of providing memory devices. Since US satellites will pass over nearly two-thirds of the earth's surface, it is impractical to establish ground stations in sufficient numbers to assure continuous monitoring and recording of satellite transmissions. With ground stations limited to reasonable numbers, the probability of obtaining significant data at the particular times when satellite signals can be monitored is not high enough—particularly in view of the nature of many of the phenomena to be studied. Therefore, memory devices are needed to store information collected during an orbit and to release data on receiving an appropriate signal from a ground station.

Each of the earth satellites to be launched by the United States during the International Geophysical Year will contain a different combination of scientific experiments. One group of satellites will telemeter

data continuously, as it is observed. A second group, either using satellite-borne tape recorders for storing synoptic data or requiring relatively high-power consumption for making measurements, will carry "command" receivers to provide data transmission upon interrogation by ground stations.

With one exception all telemetered data from US-IGY satellites will be transmitted by amplitude modulations (AM) of the signals from the radio transmitter operating at 108 mc.

Lyman-alpha Package

Instruments carried in satellites of one design will measure ultraviolet radiation in the Lyman-alpha region of the solar spectrum, satellite temperature, and the impact upon the satellite of micro-meteoric particles. The instrumentation has been developed by the Naval Research Laboratory.

Solar radiation always contains energy in the Lyman-alpha region, with marked increases occurring during periods of solar flares. The Lyman-alpha satellite experiment will study both the Lyman-alpha radiation from the quiescent sun and the peak values associated with solar flares. Solar Lyman-alpha radiation will be measured by an ionization chamber sensitive only in the desired region of the solar spectrum.

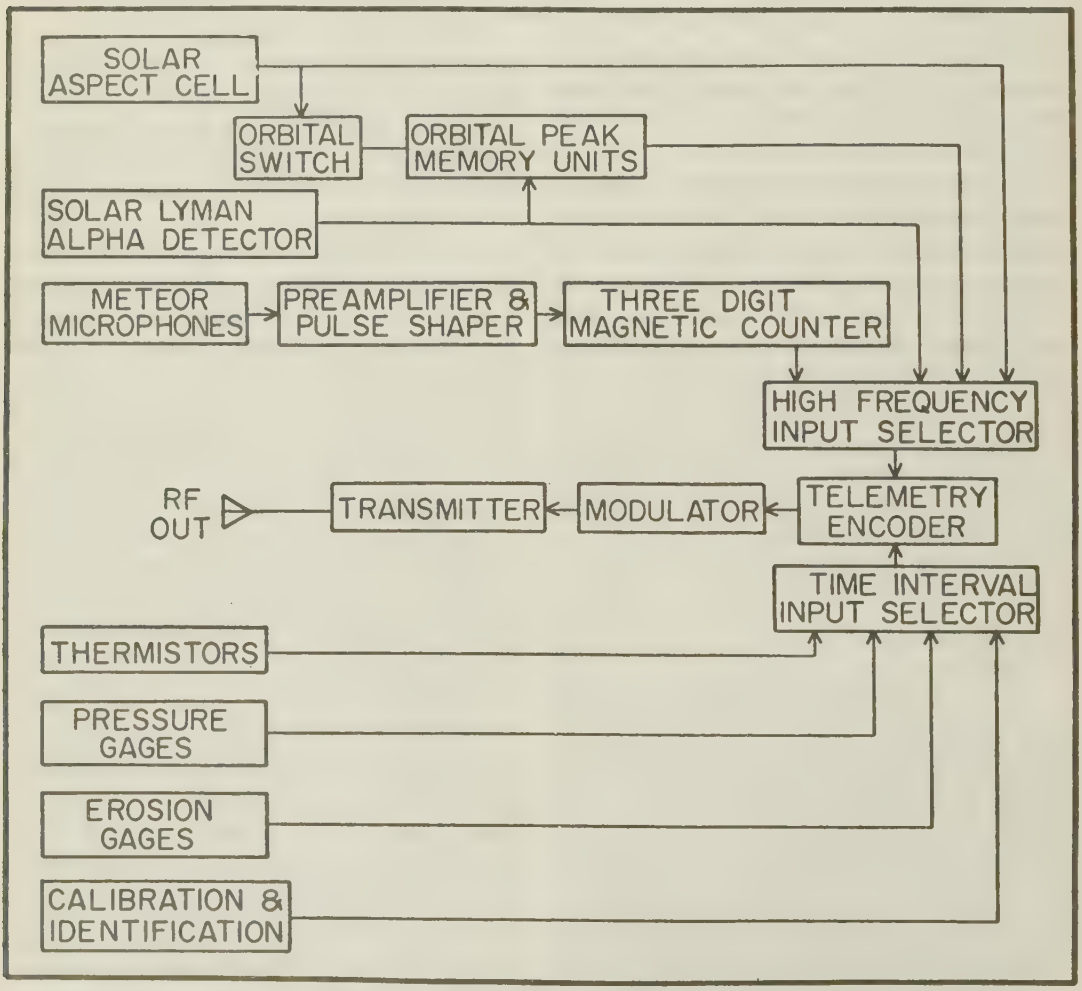

Fig. 5. *Block Diagram of Telemetry System for the First US-IGY Artificial Earth Satellite.*

In order to interpret the data recorded by the ionization chamber, the aspect, or orientation, of the satellite with respect to the sun must be known. Aspect information will be supplied by signals from silicon solar aspect cells located in the equator of the satellite.

Both internal and external satellite temperatures will be measured by means of thermistors located inside the instrument package and on the outer shell near one pole and at the equator.

The remainder of the experiments in satellites of this type are concerned with collisions between the satellite and micrometeoric particles. Three, and possibly four, types of measurements will be made. The first type will use small erosion gauges, consisting of thin film resistors coating a glass attached to the outer surface of the satellite. By monitoring the resistance of these gauges it will be possible to detect wearing away of the resistive elements by minute particles colliding with the satellite. A cadmium sulfide detector, consisting of a photo-resistive element covered by an opaque material, may be substituted for one of these erosion gauges. In sunlight, the resistance of this element will be a function of the amount of opaque material removed from the sensitive element by collision with these microscopic particles.

The third micrometeor experiment uses a group of sensitive microphones as detecting elements. Signals from these microphones, which are attached to the skin of the satellite, will drive counting circuits associated with the telemetry system; this in turn, will transmit data continuously, providing the cumulative number of collisions.

In addition to the telemetry channels required for transmitting the above data, other channels will be used to monitor battery voltages and provide calibration and identification.

Fig. 5 shows the flow of information from the detecting elements through the telemetry system and transmitter.

Signal Codes: The telemetry encoder system for the Lyman-alpha package transmits a continuous series of high-frequency audio bursts. A complete set of all input signals, called a "frame" or "scan," contains 16 bursts and 16 spaces between bursts. Intelligence is carried in (1) the burst frequency, (2) the duration of the burst, and (3) the duration of the interval

Table I. *Telemetry Channel Assignments: Lyman-Alpha Environmental Satellite*

Burst No.	High Frequency Bufst		Burst Duration		Interval Between Bursts	
	Channel	Function	Channel	Function	Channel	Function
1	A	Instantaneous Lyman-α	A1	Polar erosion A	A2	Battery volts
2	B	Solar aspect	B1	Differential pressure	B2	Short calibrate
3	A	Instantaneous Lyman-α	A1	Polar erosion A	A2	Battery volts
4	B	Solar aspect	B1	Differential pressure	B2	Short calibrate
5	A	Instantaneous Lyman-α	A1	Polar erosion A	A2	Battery volts
6	B	Solar aspect	B1	Differential pressure	B2	Short calibrate
7	C	Meteor count, units	C1	Long calibrate	C2	Battery volts
8	D	Meteor count, tens	D1	Package temperature	D2	Polar skin temperature
9	A	Instantaneous Lyman-α	A1	Polar erosion A	A2	Battery volts
10	B	Solar aspect	B1	Differential pressure	B2	Short calibrate
11	A	Instantaneous Lyman-α	A1	Polar erosion A	A2	Battery volts
12	B	Solar aspect	B1	Differential pressure	B2	Short calibrate
13	A	Instantaneous Lyman-α	A1	Polar erosion A	A2	Battery volts
14	B	Solar aspect	B1	Differential pressure	B2	Short calibrate
15	E	Meteor count, hundreds	E1	Polar erosion B	E2	Equator skin temperature
16	F	Peak Lyman-α	F1	Equator erosion	F2	Cadmium sulfide cell

between bursts. Thus, 48 potential information channels are provided, even though only 17 different data signals will be transmitted. Burst frequencies lie between 5 and 12.5 kc. Burst durations and blank intervals can vary from 4 to 30 milliseconds, although the dynamic ranges of many intervals are restricted to permit additional telemetry time for the solar Lyman-alpha experiment.

The telemetry channel assignments currently planned are shown in Table I. Transmission on Channels A and B, presenting solar Lyman-alpha and solar aspect signals are repeated several times during a scan. This frequent repetition—together with high-frequencies which permit continuously-variable signals to follow instantaneous changes—provides the necessary information from the input devices. Technical considerations dictate a similar repetition on the associated time interval channels A1, A2, B1, and B2.

The general character of a set of calibration curves for a typical telemetry encoder is shown in Fig. 6.

Cosmic-Ray Package

The satellite carrying the cosmic-ray experiment developed by the State University of Iowa will be launched by a vehicle developed by the US Army.

The radio transmission and telemetering system for the cosmic-ray satellite is being produced and assembled at the Jet Propulsion Laboratory of the California Institute of Technology.

At present, two different sets of instruments or "payloads" are being prepared. One set measures cosmic rays, meteoric density, and satellite temperatures. The other payload provides for these same measurements but adds a tape recorder, which will be geared to a ground interrogation system. The particular payload in use will be announced when the satellite is launched.

Cosmic-ray experiments: The measurement of cosmic-ray intensity outside the atmosphere of the earth and over a wide range of latitudes will provide new knowledge about these particles and about the earth's geomagnetic field. A single satellite-borne Geiger counter has been designed to measure the total cosmic-ray intensity without respect to direction. The instrument includes a storage system, which accumulates a record of the average counting rate for short periods of time. The time required for one orbit can be split into any number of segments and the average intensity for each segment can be assigned with a statistical uncertainty depending on the number of segments—the greater the number of segments the less the uncertainty.

The data to be obtained from such a system are useful for the (a) determination of the effective geomagnetic field; (b) study of time variations of primary radiation intensity, including their correlation with solar and magnetic observations and with the intensity of secondaries observed at ground stations; and (c) provide for the first time a comprehensive geographical survey of primary radiation.

Measurements of density of meteoric matter: Impact microphones (as used in the Lyman-alpha satellite) and erosion gauges, will be carried in the cosmic-ray satellite for measurements of the density of minute meteoric particles. Some of the erosion gauges are grid-like structures electrically connected in parallel. When one of the grid wires is hit by a particle physically large enough to break the wire, the over-all resistance of the string changes in a step-wise manner. Also included in the set of gauges is one composed of a very thin film of resistive material. The total resistance of this gauge will change slowly as the material is removed by the "sandblasting" action of cosmic dust, which travels at a very high velocity relative to that of the satellite. The gauges for density measurement of meteoric material were developed and provided by the Air Force Cambridge Research Center.

Telemetry equipment: Each of the payloads described above for cosmic-ray satel-

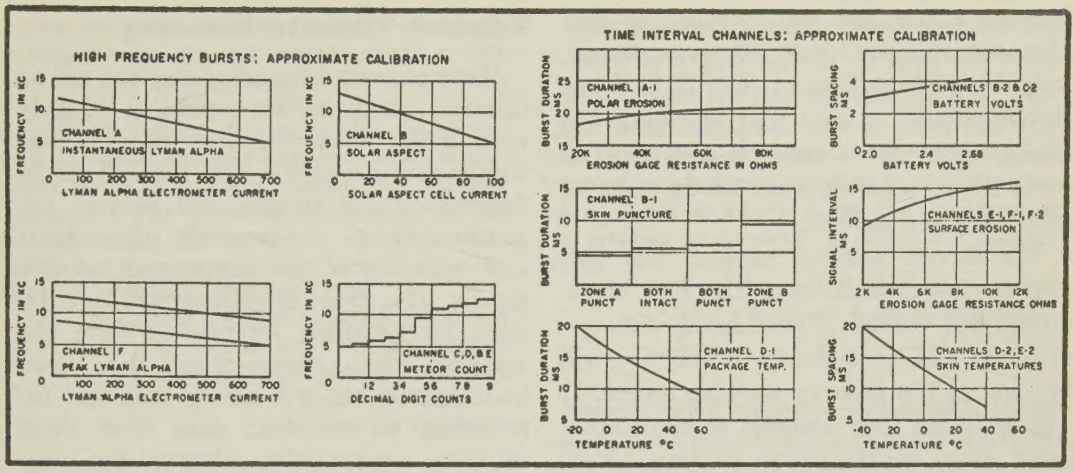

Fig. 6. *Representative Calibration Curves for a Typical Lyman-α Satellite Telemetry Encoder.*

lites will contain two transmitters; one will operate on the primary tracking frequency of 108.000 mc, and the other on 108.030 mc. Each of the two transmitters in the first payload will operate continuously and over four simultaneously used channels. One transmitter, of the Minitrack type, using a turnstile antenna, will radiate approximately 60 mw of power on 108.030 mc. It will operate from a battery supply which should enable it to transmit for approximately two weeks. The telemetering will be by AM over standard RDB telemetering Channels 2 through 5 (518 to 1320 cps).

The other transmitter will radiate approximately 10 mw of power on 108.000 mc. Its battery supply should enable it to operate for approximately two months. This transmitter will also carry information over four channels on the same RDB telemetering frequencies—in the form, however, of small-deviation phase modulation. The antenna for this transmitter will be formed by electrically splitting the satellite payload shell and driving the two pieces, thus generating a linearly polarized signal.

Although eight different telemetering channels will be available, two of these will be used in duplicate; therefore, only seven types of information will be carried. The higher-power transmitter will carry two temperature measurements: channel 2 (518–602 cps) will carry a measurement of the temperature of the outside of the payload case somewhere near the pole, and channel 3 (675–785 cps) will carry a measurement of the temperature of the interior of the transmitter. Channel 4 (888–1032 cps) will carry information derived from an impact microphone measuring the frequency of collision with micrometeors. Channel 5 (1202–1398 cps) will carry cosmic-ray information, and is of the most interest so far as telemetry reception from other parts of the world is concerned.

Channel 5 will carry information concerning measurement of the instantaneous ionization caused by cosmic radiation. The instrumentation consists of a Geiger-counter tube operating into a scale-of-32 circuit (a circuit in which 32 input signals generate one output signal). The output of the last scaler circuit controls the frequency of the telemetering subcarrier oscillator. The tone of the oscillator will change each time a new count goes into the last circuit of the scaler. The tone will shift back and forth every time 16 total counts have been received. This is expected to happen on the order of once per second.

The information from the impact microphone will be carried in a similar manner, the output of the microphone going into a

scale-of-two circuit. The channel 4 subcarrier oscillator on the higher-power transmitter will be connected to the scale-of-two circuit in such a way that the tone will change each time a count is received. Impacts are expected to occur on the order of once every few seconds.

The second satellite payload will also contain two transmitters. The first transmitter will radiate approximately ten mw of power, and, operating on 108.000 mc, will be used as the primary tracking source. It will carry the four channels of information listed above for the low-power transmitter. This payload will also include a radio receiver for interrogations from primary IGY ground stations. The cosmic-ray instrumentation in the package includes a magnetic tape recorder for the purpose of recording cosmic-ray information during each orbit. Upon interrogation from the ground, the second transmitter will switch on; the tape-recorded information will be sent over this transmitter. The higher-power transmitter will again operate on 108.030 mc with a radiated power of approximately 60 mw. As in the case of the first payload, the low-power transmitter will send through a linearly polarized antenna, the high-power one through a turnstile.

Volunteer Telemetry Recording

Primary ground recording stations will be installed along a line extending roughly north-south down the east coast of the United States and the west coast of South America. These stations will provide approximately a one-per-orbit observation and recording of the telemetered satellite signals. This chain of stations will be sufficient for recording information from the satellites which release stored data upon interrogation but will not be sufficient for recording all pertinent data from those satellites transmitting observations continuously.

With the cooperation of British National Committee for the IGY and of local groups who will operate the equipment, two special telemetry receiving stations have been established in strategic positions near the geomagnetic equator at Ibadan, Nigeria, and at Singapore.

The US National Committee for the IGY solicits the assistance of all persons and organizations equipped to make tape recordings of satellite signals. Instructions on recording techniques and procedures for forwarding the tapes to the cognizant organizations are covered in the January 1958 issue of QST, the journal of the American Radio Relay League.

IGY Satellite Program Notes

The following report is reproduced from Science, *Vol. 126, p. 1334, Dec. 27, 1957.*

Soviet Satellite Carrier Rocket

On 8 December 1957 the president and the chief scientific secretary of the U.S.S.R. Academy of Sciences addressed a cable to the president of the U.S. National Academy of Sciences regarding the rocket carrier body of the first artificial earth satellite, which was launched on 4 October 1957. A similar cable was addressed on 9 December to Joseph Kaplan, chairman of the U.S. National Committee for the International Geophysical Year, by Academician I. P. Bardin, president of the Soviet IGY Committee. Because the substance of these two cables is identical, only the first is quoted:

DETLEV BRONK, *President*
National Academy of Sciences

According to available data some not entirely burnt remnants of the first earth satellite rocket have been scattered along a line including Alaska

and the west coast of North America. A thorough investigation of the not entirely burnt rocket remnants and the knowledge of the exact places of their fall are of great scientific significance as they provide valuable data concerning phenomena occurring when satellites enter the denser atmospheric layers. The USSR Academy of Sciences asks all the USA scientists to communicate the data concerning the fall of the rocket remnants and to send the remnants which were found to the Academy of Sciences Moscow USSR.

President of USSR Academy of Sciences
ACADEMICIAN A. N. NESMEYANOV
Chief Scientific Secretary of USSR Academy of Sciences
ACADEMICIAN TOPCHIEV

Although no evidence had come to light indicating that the rocket body of the first satellite had fallen in North America, a review of all available data and reports was initiated on 6 December when press dispatches from Moscow indicated that the U.S.S.R. believed the carrier body may have fallen on this continent. The results of this review, as of 11 December, were negative, and, on the same day, the president of the National Academy of Sciences accordingly addressed the following reply to the U.S.S.R. Academy:

PRESIDENT A. N. NESMEYANOV
Academy of Sciences of U.S.S.R.
Moscow

Reference your message and message Bardin to Kaplan our review thus far of sightings and trackings of satellite and investigation of reports of objects sighted do not indicate rocket or remnants fell in United States or its territories. We have no reports of finding of any such bodies. Your request being transmitted to trackers and others. It will be helpful if you can provide data you mention as available to guide our further search.

DETLEV W. BRONK, *President*
National Academy of Sciences
U.S.A.

Several observation programs are under way in the United States as part of the IGY effort in the tracking of all satellites. Photographic and visual tracking responsibilities have been assigned to the Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge 38, Mass. Radio tracking responsibilities have been assigned to the Naval Research Laboratory, Washington 25, D.C. Reliable information on satellite sightings would be welcome. Photographic and visual data should be addressed to the Smithsonian Astrophysical Observatory and, similarly, radio data to the Naval Research Laboratory.

HUGH ODISHAW

USNC-IGY

Thule Neutron Monitor Station

This report is based on material provided by Martin A. Pomerantz of Bartol Research Foundation. The Thule monitor was constructed by the Foundation and is operated by the U.S. Army Signal Corps.

The neutron monitor installation in Thule, Greenland (76.5°N, 68.8°W) was completed and put into operation on 27 August, completing an Arctic chain of three neutron monitor stations. Observations made at Thule are particularly significant because this station, at geomagnetic latitude 88°N, is closer to the geomagnetic pole than any other neutron monitor installation.

Because of the deflecting effect of the earth's magnetic field, more cosmic rays reach the surface of the earth in high geomagnetic latitudes than in lower latitudes. Only high-energy atomic particles can reach the earth at the geomagnetic equator but the velocity requirement is reduced as the poles are approached.

Most of the cosmic rays that reach sea level are mesons—the so-called hard component. These particles are unstable and disintegrate a short time after they have been produced in interactions between the relatively high-energy primary cosmic rays

and the atmosphere at very high altitudes. Their intensity near sea level depends in a very complicated manner on continually changing meteorological conditions throughout the atmosphere up to the point of origin.

In contrast, the nucleonic components, although comprising only a small fraction of these secondaries that reach the earth's surface, consist of protons and neutrons produced in the atmosphere by incoming low-energy cosmic rays and do not display the meson dependence upon meteorological conditions. Hence, by confining attention to the nucleons much information can be obtained about the geographic distribution of cosmic rays and of the earth's magnetic field.

A neutron monitor of the type installed at Thule detects the secondaries of the relatively low-energy cosmic rays, upon which the effects of magnetic conditions in the vicinity of the earth are most pronounced. A decrease in cosmic-ray intensity, as a consequence of either deflection or deceleration of these particles, is often associated with magnetic storms. Rapid increases in the cosmic-ray intensity sometimes occur simultaneously with eruptions on the solar disk. These often coincide with ionospheric disturbances causing radio blackouts.

The basic arrangement for measuring the intensity of the nucleonic component comprises a structure, called a "pile," in which several neutron detectors (boron trifluoride proportional counters containing BF_3 gas enriched with B^{10}) are embedded. The pile itself, consisting of lead and paraffin, contains a material of high atomic weight (lead) in which incoming nucleons can interact; a number of neutrons are produced in each of the resulting explosions. A neutron moderator (paraffin) slows these disintegration products down and retains them until ultimately they pass through one of the proportional counters that serve as neutron detectors. In some respects, this structure resembles an atomic reactor, except that in this case, the nuclear fuel is the nucleonic component of cosmic rays.

Each of the counters embedded in the pile actuates completely independent electronic circuits, so that the failure of any single component is easily recognizable. The scaled counts are tallied by a printing numerical register, as well as by an operation recorder pen which enters a pip on a continuously-moving chart driven by each counter. A chronometer with electrical contacts causes the reading on the register, and the corresponding time, to be printed on tape every 15 minutes. The impulses from the counters are also combined and introduced into a counting-rate computer, which indicates the average number of counts per minute. This is recorded on a chart continuously moving at a speed of six inches per hour. This makes it possible to correlate the time-variation of any unusual changes in the cosmic-ray intensity with other geophysical or solar disturbances.

A detailed comparison of time variations and distinctive events occurring near the geomagnetic pole, but at widely different longitudes, is being carried out with two other stations located at Resolute Bay, (74.7°N, 94.9°W) and at Murchison Bay, Spitzbergen (80.0°N, 19.0°E). These are under the direction of D. C. Rose, National Research Council of Canada, Ottawa, and A. E. Sandström, Fysiska Institutionen, Upsala, Sweden, respectively.

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